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RE-OPENING OF THE TEMPORARY SEISMIC STATION AT KLOKOČOV (KLOK)

ZAHÁJENÍ PROVOZU DOČASNÉ SEISMICKÉ STANICE KLOKOČOV (KLOK)

Abstract

In the mid-January, 2007, was re-opened the Klokočov (KLOK) seismic station. The essential goal of this station was detection of weak tectonic microearthquakes on the territory of northern Moravia and Silesia. Its usefulness was documented after just 2 months, when on January 31 was recorded an earhquake located close to Šumperk. Within this time interval also a few microearthquakes were recorded and evaluated by the Institute of Physic of the Earth, Masaryk University in Brno, the focal region of which was determined to broader vicinity of Šternberk. Moreover, the KLOK seismic station observed induced seismic events from the coal mines in the eastern part of the Ostrava-Karviná Coal Basin and a lot of quarry blasts as well. On seismograms of quarry blasts carried out in the quarry Jakubčovice nad Odrou there was detected also acoustic wave which made it possible to estimate the epicentral distance between quarry and seismic station KLOK. As an interesting phenomena can be considered a passage flight of a fireball above south Moravia which was observed at several seismic stations.

Key words: seismic network, seismological observation, microeartquake, quarry blasts

Introduction

The Klokočov (KLOK) seismic station was put back into operation in mid-January 2007 after the interruption that lasted a little more than one year. Between 2003 and 2005 it was used for the seismological research in the framework of the grant project GA CR No. 205/03/0999, as described by Růžek et al. (2004), and Holub (2005). At present it became part of the local seismological network operated by the Institute of Geonics AS CR.

At present, this station is included in the network consisting of the following seismic stations: Ostrava-Krásné Pole (OKC), Zlaté Hory (ZLHC) and Raduň (RADC). It also substituted the Slezská Harta (SHAC) seismic station which has recently been closed. The seismological network is operated by the Institute of Geonics AS CR Ostrava. Its main aim is to detect local microearthquakes and quarry blasts on the territory of northern Moravia and Silesia and, moreover, to detect stronger mining induced events originating in mines situated in the eastern part of the Ostrava-Karviná Coal Basin.

The usefulness of this station showed after just a few months. Station KLOK detected a local earthquake occurring near the town of Šumperk, and also several weak microearthquakes. A preliminary location of their foci, carried out by the Institute of Physics of the Earth, Masaryk University (IPE) in Brno, situated them to the region approximately 10 kms NE of Šternberk in the Jeseníky Mts. Data from the KLOK station were included in the location procedure. Aside from these microearthquakes, a number of quarry blasts and strong induced seismic events were detected and interpreted. Several types of them are determined below, e. g. a local microearthquake, a quarry blast with and/or without a detected acoustic wave at the rear of the record, a mining induced seismic events, and a passage flight of a fireball above southern Moravia.

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Position and instrumentation of the seismic station

The KLOK seismic station is situated on the outskirts of the Klokočov village near Vítkov, district Nový Jičín. Its position is defined by geographical coordinates $\varphi = 49^0 45.35'$N, $\lambda = 17^0 43.17'$E and $h \approx 600$ m m.s.l. and shown in Fig. 1.

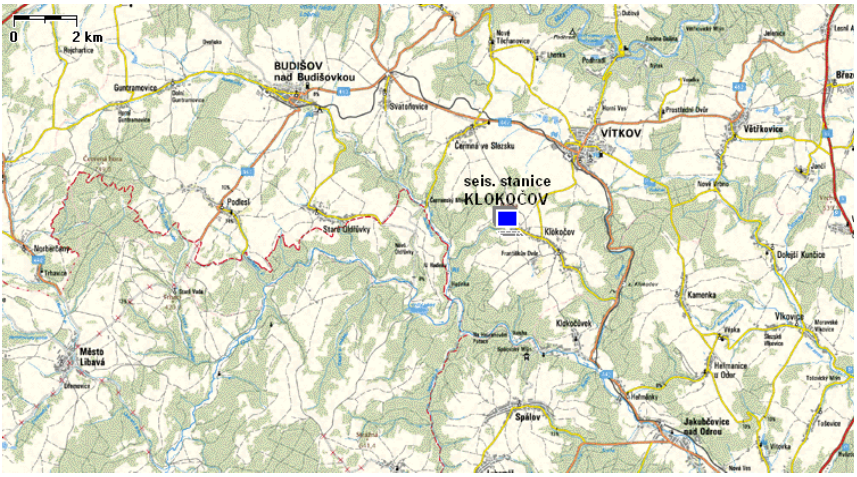

Fig.1 Situation in the vicinity of the Klokočov (KLOK) seismic station.

Station KLOK is equipped with the mobile data aquisition system GAIA 2; timing is controlled by GPS signals, sampling frequency is 100 Hz, the recording medium is represented by two 1-GB flashcards. A three-component seismograph ViGeo 2 with eigen-frequency $f_0 = 2$ Hz and velocity output of 400 Vs/m is used as a sensor; the dynamic range for the frequency 10 Hz $\approx$ 140 dB, and the working range $f \approx$ 2-200 Hz.

The data acquisition system works in a continuous regime, as at the OKC seismic station and unlike the ZLHC and RADC seismic stations that are operated in a triggered regime (Kaláb and Knejzlík, 1999; Boráňová et al., 2001).

Interpretation of seismograms

The arrival times of body waves Pg and Sg were first picked on unfiltered seismograms (velocigrams) of seismic events. The accuracy of detected times due to using sampling frequency of 100 Hz was 0.01 s. Records from quarry blasts were interpreted in which surface waves were also observed. Attention was paid to group velocities dispersion of Rayleigh waves, which enabled us to construct and evaluate dispersion curves of these group velocities.

Seven microearthquakes were detected approximately in the first two months of the operation of the KLOK station. These events were located at IPE by the HYPO3D program (Firbas and Werl, 1988), which uses the method of iterative computation of the raypath through a 3-D velocity model (Špaček et al., 2006). All available data were used for the location – data from the UGN AS network, IPE stations, and stations operated by the Geophysical Institute AS CR Prague. Local magnitudes ML were determined from maximum vertical trace amplitudes of Sg waves (for IPE stations only), using Scherbaum and Stoll's (1983) formula for local events. The generalized map of the northern Moravia and Silesia with the seismic station positions and epicenters of microearthquakes is shown in Fig. 2.

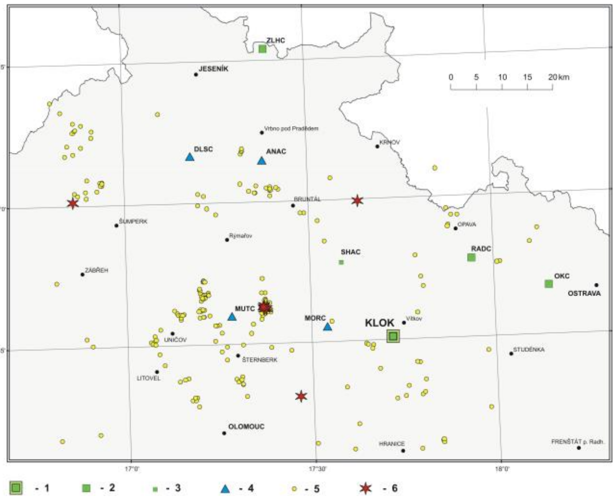

Fig.2 Generalized map of the northern Moravia and Silesia.
1 – Seismological station Klokočov (KLOK)
2 – Other stations of the Institute of Geonics AS CR Ostrava
3 – Closed station Slezská Harta (SHAC)
4 – Stations of the Institute of Physics of the Earth Brno (IPE)
5 – Epicenters of earthquakes localized by IPE Brno in 1996-2006
6 – Epicenters of earthquakes localized using also data from the KLOK station in 2007

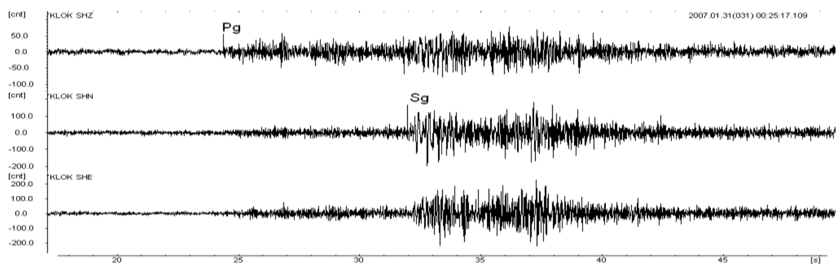

Fig.3 Seismograms of the local microearthquake observed at the seismic station KLOK. This earthquake originated on January 31, 2007, at 00^h25^m UTC and was located by the stations of the Czech regional seismological network to the vicinity of Šumperk.

Two microearthquakes (M_L=0.0) were detected on January 14, 2002. The first one at 01:26 UTC was located on the territory of northern Moravia near the Sosnová village, district Bruntál, while the second one at 23:10 UTC was positioned to southern Moravia, roughly to the vicinity of Olomouc. The strongest microearthquake from the above-mentioned series was observed from the area near the village of Bušín, NW of Šumperk, on January 31, 2007, at 00:25 UTC, and its local magnitude M_L amounted to 1.1. The respective seismograms from the seismic station KLOK are shown in Fig. 3. Finally, four weak microarthquakes (maximum M_L = 0.1) were detected between February 2 and 7. Their character was very similar and their foci were estimated into the known epicentral area Rýžoviště, 10 kms NE of Šternberk (Havíř, 2002). The occurrence of these microearthquakes within a relatively short time interval can be classified as a minor earthquake swarm.

Among different seismic events also mining induced events from the Ostrava-Karviná Coal Basin were recorded daily. The mining event which occurred in the ČSA Mine is displayed in Fig. 4. Station KLOK also frequently recorded blasts from quarries as well. Characteristic feature of these blasts are very intensive surface Rayleigh waves as it is documented in Fig. 5.

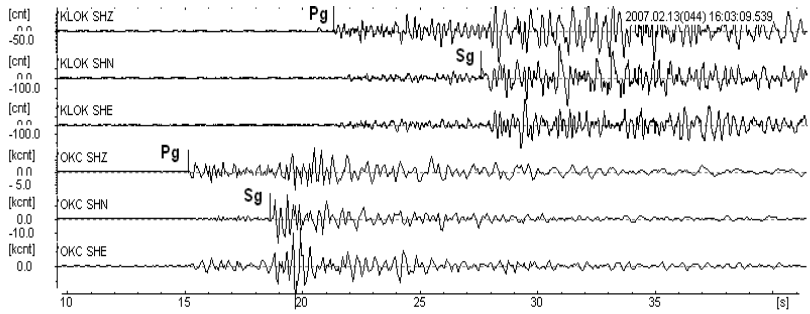

Fig.4 Records of the seismic induced event from the Ostrava-Karviná Coal Basin which occurred in the ČSA Mine on February 13, 2007, at $16^{h}\ 03^{m}$ UTC, with the energy of $E \approx 1.6\text{x}10^{6}$ J. The upper part of the figure shows records from the KLOK station at the epicentral distance of d ≈ 56.0 km, the lower part represents seismograms from the seismic station OKC at the epicentral distance of d ≈ 24.6 km.

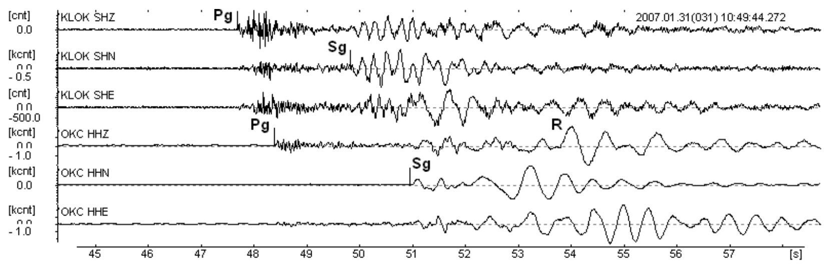

Fig.5 Records of the blasting operation performed in the quarry Kajlovec near Hradec nad Moravicí on January 31, 2007, at $10^{h}\ 49^{m}$ UTC, the amount of explosives Q = 6 623 kg. The upper part of the figure shows records from the KLOK station at the epicentral distance of d ≈ 16 km, the lower part the records from the OKC station at the epicentral distance of d ≈18.6 km.

The existence of short-period Rayleigh waves is applicable for construction of observed dispersion curves of group velocities using, e.g. graphical-numerical method. The interpretation of these dispersion curves is usually aimed at determination of a simple shallow structure model composed of a layer or layers on a half-space. An example of practical procedure of interpretation of dispersion curves of Rayleigh waves observed on the territory of our interest was described by Holub et al. (2006).

Acoustic waves

Acoustic waves are very frequently generated by blasting operations in the open-pit mines or quarries where explosions are carried out near the surface or on the very surface, e.g. by using an external charge for disintergrationg large boulders. Records of acoustic waves caused by two blasts fired in the Jakubčovice nad Odrou quarry and detected at the KLOK seismic station could serve as an example in Fig. 6.

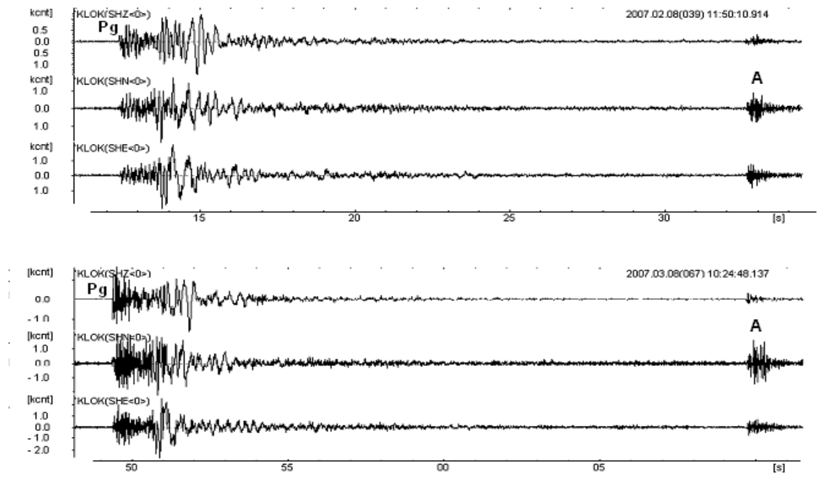

Fig.6 Illustrations of the onset of an acoustic wave recorded at the KLOK seismic station during the quarry blast in Jakubčovice nad Odrou: February 8, 2007, Q = 5 445 kg, d = 7.24 km (the upper part of the figure), March 8, 2007, Q = 5 612 kg, d = 7.34 km (the lower part of the figure).

The estimation of the distance between the quarry and the seismic station was based on readings of the arrival times of the P-wave and the acoustic wave A. The derivation of general formulae for distance calculation was essentially based on the following relations:

$$t_P = d/v_P \quad \text{and} \quad t_A = d/v_A , \tag{1}$$

where:

t_P and t_A … arrival times of P and acoustic waves A in [s]

v_P and v_A … propagation velocities of P and acoustic waves [m/s]

d ….. epicentral distance [m].

As for the difference of the arrival times of both waves, the following relations are valid:

$$t_A - t_P = d/v_A - d/v_P \tag{2}$$

$$t_A - t_P = [(v_P - v_A)/v_P v_A] \cdot d \tag{3}$$

$$d = (t_A - t_P)\ [v_P v_A/(v_P - v_A)]. \tag{4}$$

Taking into account the basic physical laws for the spreading of acoustic waves, two different values of sound (acoustic) velocity were found in the literature due to different approaches to the solution of this problem. For instance, Newton derived the value $v_A \approx 280$ m/s under the assumption that he knew the dependence of pressure p on the bulk density ρ. Then he assumed that this dependence corresponded to the Boyle-Marriote law, wherever the isothermic process took place.

Opposite to that, Laplace presumed that this process should be understood as an adiabatic process, and he denoted this velocity as an adiabatic velocity of sound $v_A \approx 332$ m/s (Brdička, 1959). Nevertheless, the velocity of the acoustic wave $v_A = 337.6$ m/s given by Valouch (1929) was implemented to our computations.

Introducing defined values of velocities and arrival times of P and acoustic wave A

$v_P = 5840$ m/s (Růžek et al., 2004)

$v_A \approx 337.6$ m/s (at the temperature of 10oC , not taking into account the moisture and the atmospheric pressure - Valouch, 1929)

$t_A - t_P = 20.205s$ (1) $t_A - t_P = 20.37s$ (2)

the respective epicentral distances were calculated.

The distance $d_1 = 7239$ m for the quarry blast (1) performed on February 8, 2007, was calculated using the formula (4), while $d_1 = 7245$ m was computed by means of rectangular coordinates within the Křovák´s net. The same approach was chosen in calculating the second quarry blast from March 8, 2007. The results represent the following values: $d_2 = 7298$ m and $d_2 = 7341$ m.The errors of interpreted and computed distances do not exceed 1%.

For the estimation of epicentral distance between the quarry and the seismic station, the modified equation (5) can be applied:

$$d\,[\text{km}] \approx 0{,}4\,[\text{s}] \cdot (t_A - t_P)\ [\text{km/s}]. \quad (5)$$

Similar effects of explosions were described by Zátopek (1949), who recognized that some annular stripes of audibility (approx. up to 60 kms) exist around these explosions, while there is a stripe of inaudibility at the distance of 60 to 160 kms. By analyzing the physics of these waves he deduced that the second and further stripes of audibility cannot originate by the normal spreading of sound with concentrated spherical wavefronts and linear rays, which implies that sound waves spread in an anomalous way. The arrivals of acoustic waves are also observed during seismic reflection and/or refraction field experiments in which shallow boreholes for shots are applied. These shots then generate strong acoustic waves having the character of longitudinal waves with velocity of around 340 m/s (Mareš et al., 1979).

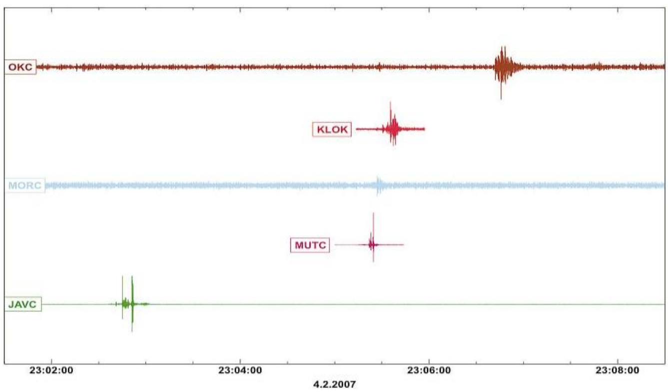

Fig.7 Records from the seismic stations KLOK, OKC, JAVC, MORC, and MUTC during the passage flight of a fireball above southern Moravia on February 4, 2007, approx. at 23^h00^m UTC.

An interesting example of „non-seismological“ use of the seismological station is the fireball registration shown in Fig. 7. The KLOK station, as well as other stations in the NE part of the Czech Republic, recorded on February 4, 2007, after 23:00 UTC – sound waves resulted from the penetration of meteoric bodies through the atmosphere. The fireball collapsed at the height of about 37 kms above Earth's surface near Břeclav. Seismic registrations of sound effects helped with the location of its trajectory and the point of the destruction (Kalenda P., Borovička J., Spurný P. – personal communication).

Conclusions

The presented conclusions are based on the interpretation of data observed at the re-opened temporary seismic station in Klokočov (KLOK):

- the KLOK station substitutes the closed station Slezská Harta (SHAC) inside the local seismic network operated by the Institute of Geonics AS CR
- its operation proved a suitable siting which seems to be closer to the focal region of microearthqauakes between the regional seismic stations Ostrava-Krásné Pole (OKC) and Moravský Beroun (MORC)
- during roughly two months of operation station KLOK detected seven microearthquakes, several intensive mining induced seismic events from the Ostrava-Karviná coal mines and a lot of quarry blasts conducted in the Moravo-Silesian region
- the advantage of continuous recording was documented by the detection of weak microearthquakes, which did not trigger the apparatuses PCM3 installed at the seismic stations Zlaté Hory (ZLHC) and Raduň (RADC)
- the location of seismic events discussed in this paper was performed by the Institute of Physics of the Earth in Brno, and readings of the KLOK station were also included into the location procedure
- blasting operations from the Jakubčovice nad Odrou quarry were recorded frequently. Two explosions were accompanied with a distinct onset of an acoustic wave. Using the arrival times of the P and the acoustic wave A, an approximate formula for the estimation of the epicentral distance was derived, i.e. d [km] = 0.4 [s] . ($t_A - t_P$) [km/s]. The differences between distances calculated from rectangular coordinates, and derived from the P and acoustic waves, did not exceed 1%
- sound effects on February 4, 2007, after 23:00 UTC, which occurred after the collapse of a fireball at the height of about 37 km, which were recorded at several seismic stations, helped location the trajectory of the bolid and its destruction point.

Naformátováno: Odrážky a číslování

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